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FOR SCOTLAND

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1968 No. 2

The Food of Seals in Scottish Waters

By BENNET B. RAE
Marine Laboratory, Aberdeen
January, 1968

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CONTENTS

	Page
INTRODUCTION	3
SOURCES OF MATERIAL	3
Place of Origin	3
Seasonal Abundance	3
Methods by which Seals were Procured	4
Length Distribution of the Seals Examined	4
PROPORTION OF EMPTY STOMACHS AND GENERAL FEATURES OF THE STOMACH CONTENTS	4
THE FOOD OF GREY SEALS	10
Comparison of the Food of Grey Seals from Different Sources	11
Seasonal Differences	12
Quantitative Examination of Stomach Contents	12
Circumstantial Evidence	13
Regional Differences in the Food	13
Orkney	14
Shetland	15
Evidence from Commercial Sources	15
THE FOOD OF COMMON SEALS	16
DISCUSSION ON THE FOOD OF SEALS	17
The Distribution of Grey Seals	17
Are Seals Significantly Pelagic?	18
The Availability of Different Species of Fish in Coastal Waters	20
ACKNOWLEDGEMENTS	21
SUMMARY	21
REFERENCES	22

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The Food of Seals in Scottish Waters

INTRODUCTION

Following a review of the published accounts of the food of the grey and common or harbour seals throughout the world, supplemented by practical investigation of this subject in the Scottish area from 1958 to 1960, it was concluded that these animals feed predominantly on fish and that the types of fish eaten in any locality depend chiefly on the species which are most numerous or most readily available (Rae, 1960). After the publication of the preliminary Scottish observations, a brief account of the food of grey seals, including additional material, was reproduced in the Report of the Consultative Committee on Grey Seals and Fisheries (1963). Since that time many more seals have been examined at the Marine Laboratory, Aberdeen (in a few instances only the heads and stomachs were procured). Up to the end of 1966, these, combined with the earlier records, number 322 grey seals and 175 common seals. In addition, the stomach contents only of 46 grey seals killed in Orkney and Shetland have been provided by Mr E. A. Smith, formerly Grey Seals Officer to the Nature Conservancy.

SOURCES OF MATERIAL

The seals examined and identified at the Marine Laboratory since 1958 have been procured from different sources and by different means. This has been possible through the co-operation of salmon fishermen, white fish fishermen, and hunters throughout the country.

Place of Origin

The numbers of grey and common seals obtained from the different counties or localities of Scotland, and including a few from the English and Welsh coasts, are given in Table I and Figure 1. Although most of the seals came from the Scottish east coast, especially from the section extending from the Firth of Tay to the Dornoch Firth, others were procured from many different localities, so that in general the animals originated from areas exhibiting a variety of physical and environmental conditions. It should be emphasised, however, that the seals examined at Aberdeen represent only a proportion, probably a small proportion, of all those killed or found drowned in nets or shot by hunters in the protection of fishing gear. This is perhaps best illustrated by Table II, which gives the numbers of seals definitely known to have been killed by representatives of the district boards in one area, the southern shore of the Moray Firth. Although most of the animals in Table II were undoubtedly common seals, it is noteworthy that of the 65 seals from this area examined at the Marine Laboratory since 1958, 43 were grey seals and only 22 were common seals. The explanation is that most of the animals received at the laboratory were from coastal districts where the grey seal is more plentiful than the common.

Seasonal Abundance

The numbers of seals examined each month since the beginning of 1958 are given in Table III. This shows that seals are active on the coast at all times of the year, but it is also evident that the numbers of the two species vary according to the season. Grey seals taken in coastal areas would appear to be most numerous from January to August with a peak from February to April. This peak coincides with the beginning of the netting season for salmon (mid-February to the end of August or mid-September), and to some extent with the local set-net fishery for cod on the coasts of Angus and Kincardineshire (beginning of December to the end of February). The apparent scarcity of grey seals from September to November may therefore arise partly as a result of the cessation in these months of the two chief passive methods of fishing on the coast, fixed coastal nets for salmon and set-nets for cod, i.e., those most productive of seals. A decline in the numbers of grey seals examined, however, is evident from April to August. This would seem to be explained partly by the destruction

of seals in nets and by shooting at the beginning of the salmon netting season, but perhaps even more so by the gradual withdrawal of adult seals to the breeding grounds as the summer progresses. In December the numbers of grey seals again begin to increase with the advent of newly weaned pups and adults from the breeding grounds.

TABLE I

NUMBERS AND PLACES OF ORIGIN OF SEALS EXAMINED AT THE MARINE LABORATORY, ABERDEEN 1958–1966

	Grey Seals	Common Seals		Grey Seals	Common Seals
Yorkshire	1	—	Dornoch Firth to Caithness	12	9
Northumberland	3	—	N.W. Scotland (N. Minch)	5	1
Berwickshire	2	—	Argyllshire	6	2
Firth of Tay (Fife)	53	105	Ayrshire	1	1
Angus	70	26	Solway Firth	5	—
Kincardineshire	99	12	North Wales	2	—
Aberdeenshire	21	5	Orkney	19*	—
Banffshire	28	5	Shetland	27*	—
Moray and Nairn	14	9	Totals	368	175

*Stomachs only, material provided by Mr E. A. Smith.

TABLE II

SEALS KILLED BY DISTRICT BOARDS AND REPORTED TO THE MORAY FIRTH SALMON FISHERIES COMPANY FROM 1956 TO 1966

	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Deveron	—	—	—	1	11	9	6	6	7	8	6
Spey	4	16	14	6	26	10	8	13	17	15	9
Findhorn	13	14	6	11	9	11	17	16	8	4	33
Nairn	1	2	2	—	—	1	1	2	2	1	3
Ness	21	9	16	5	7	11	7	5	9	3	9
Conon	—	17	23	31	53	31	27	12	17	18	21
Kyle of Sutherland	113	131	204	356	188	118	102	83	93	111	79
Beauly	20	27	21	—	13	8	16	26	23	41	51
Totals	172	216	286	410	307	199	184	163	176	201	211

Most of the common seals (Table III) were obtained from May to October. The high monthly total in August is perhaps somewhat fortuitous as it includes the results of an effort to reduce the numbers of this species on the sandbanks of the Firth of Tay in 1961 and 1962. Most of the common seals were killed in the Firth of Tay, while others were obtained from or near other estuaries, thus indicating the preference of this species for relatively sheltered waters.

Methods by which Seals were Procured

From the commencement of these investigations the seals examined at Aberdeen were obtained by different means. Table IV shows that of the 322 grey seals, 158 were found drowned or were killed in salmon nets, 37 in white fish gears and 127 were shot in the sea or on a beach at distances from salmon or white fish nets varying from a few yards to 20 miles or more. This last category includes seals killed during the close season, when salmon fishing is suspended.

Similarly of the 175 common seals, 25 were killed in salmon nets, two in codnets and 148 were shot in the water, on sandbanks or on beaches.

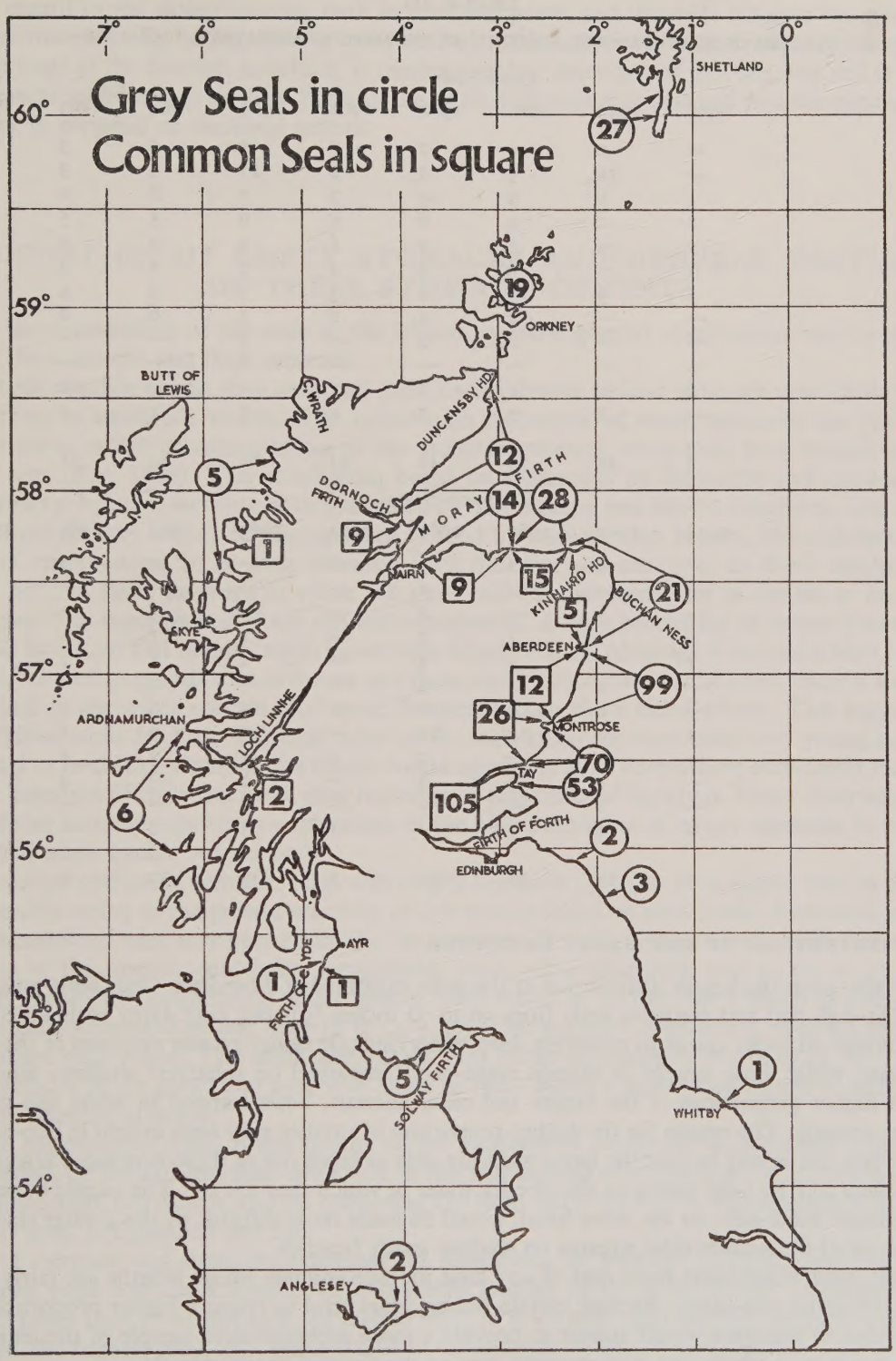

Fig. 1. Numbers of seal stomachs examined from various counties or localities.

TABLE III

NUMBERS OF SEALS EXAMINED MONTHLY AT THE MARINE LABORATORY, 1958–1966

Grey Seals

	1958	1959	1960	1961	1962	1963	1964	1965	1966	Totals
January	—	2	—	2	7	3	5	3	4	26
February	—	11	3	7	2	17	5	3	1	49
March	1	6	3	10	7	7	8	2	9	53
April	2	2	4	6	5	9	5	5	5	43
May	2	—	5	3	1	5	4	4	6	30
June	1	—	4	3	1	7	5	5	2	28
July	1	3	5	8	3	7	5	4	1	37
August	—	—	4	2	2	3	6	2	5	24
September	—	—	1	2	—	1	—	—	—	4
October	—	—	—	—	—	1	—	—	—	1
November	2	—	1	2	1	—	—	1	1	8
December	—	8	2	3	2	1	1	2	—	19
Totals	9	32	32	48	31	61	44	31	34	322

Common Seals

	1958	1959	1960	1961	1962	1963	1964	1965	1966	Totals
January	—	—	1	3	—	—	—	1	—	5
February	—	—	1	1	—	—	—	—	1	3
March	—	3	—	4	—	—	3	—	—	10
April	2	1	1	2	—	1	1	—	—	8
May	1	1	5	3	—	1	8	1	—	20
June	—	1	1	1	—	—	2	—	—	5
July	—	2	9	7	—	1	8	1	—	28
August	2	3	12	29	—	3	7	1	1	58
September	—	—	—	7	1	—	2	1	1	12
October	—	1	1	3	—	2	—	4	2	13
November	—	1	—	—	—	4	—	—	—	5
December	2	2	1	—	1	1	1	—	—	8
Totals	7	15	32	60	2	13	32	9	5	175

Length Distribution of the Seals Examined

Table IV also gives the length distribution of the seals examined at Aberdeen. Grey seals ranged from 36 to 97 inches (91–246 cm) and common seals from 36 to 72 inches (91–183 cm). Grey seals killed in salmon bag-nets (employed on rocky coasts in relatively deep water) include rather greater numbers of the smaller and younger animals, while those caught in salmon stake-nets (employed on relatively shallow, sandy beaches) include rather higher proportions of the bigger and older animals. Seals trapped in white fish gear are also mainly smaller animals. The reason for the higher proportion of smaller grey seals caught in bag-nets and cod-nets is not obvious but it may be that the larger seals are able to break out of these nets more readily when the nets are stretched taut by tidal action in the deeper water in which they are set. The escape of seals, large or small, from salmon stake-nets on the other hand, would be made more difficult by the greater elasticity of the netting as a result of the weaker tidal streams on shallow sandy beaches.

In contrast, seals killed away from nets of any kind include animals whose lengths are fairly evenly distributed over the entire size-range. Because certain fishing gears tend to retain a higher proportion of smaller animals, seals shot in the open would appear to provide a more representative sample of the length-range of the grey seal stocks as a whole and consequently also of the food of these animals.

In contrast to the grey seal records, 85% of the common seals examined were shot in the water or on beaches; like the grey seal, however, these covered the entire length-range. Furthermore, most of the 27 common seals killed in fishing gear were in the lower half of the size-range.

Having regard to the varied sources, both in time and place, and the wide range in the size of the seals examined, the material may be regarded as qualititatively, although not quantitatively, representative of seal stocks on the coast of the Scottish mainland. It confirms earlier observations that the grey seal is considerably more troublesome to fishermen on open Scottish coasts than the common seal and that the common seal is the chief predator in estuarial or sheltered waters.

PROPORTION OF EMPTY STOMACHS AND GENERAL FEATURES OF THEIR STOMACH CONENTS

During the examination of the seals at the laboratory some general observations were recorded on the condition of the stomachs and their contents.

Of the total number of 322 grey seals 146 (45%) were devoid of food although most of them contained varying numbers of nematode worms. The rather high proportion of empty stomachs has previously been attributed to some extent to regurgitation of the stomach contents when seals find themselves unable to escape from nets (Rae, 1960). This conclusion, based on statements by fishermen and the examination of material thrown up by seals, has now been confirmed by both salmon and lobster fishermen, who on a number of occasions have actually witnessed regurgitation of food by seals trapped in nets. Nevertheless the variable percentages of empty stomachs in seals obtained from different sources (37% in those caught or killed in salmon nets, 30% in those drowned in white fish gear, and 60% in those shot in the sea or on sand banks) seems to suggest that regurgitation is not the sole explanation. A high percentage of empty stomachs has also been observed by Fiscus and Baines (1966) in sea lions killed on land. Although it has not always been possible to distinguish between grey seals shot in the sea and those shot on sand banks or beaches, there is some evidence that those killed in the water contain food more frequently than those killed ashore. This suggests that the former were killed while feeding. Although a few of the seals killed on shore were very young animals which had not started to feed after weaning, the others would appear to have been ashore sufficiently long to permit the complete digestion of their last meal, thus indicating a rapid rate of digestion. These observations however do not provide an entirely satisfactory explanation of the high proportion of empty stomachs in those animals which are killed while hauled out on land.

The overall proportion of common seals with empty stomachs (57%) is even higher than in the grey seal, but this is possibly owing to the greater numbers of this species killed on sand banks. Moreover, eleven of the common seals examined were very young animals, the stomachs of which contained only milk, and consequently the proportion of this species containing recognisable food, other than milk, was as low as 37%.

Relatively few of the stomachs of either species were found to be full; the greatest quantity of food in any single stomach amounted to just over 10 lb (4·5 kg). The majority contained a relatively small quantity of food and some only traces. The small amount of food in the stomachs of so many of the seals and the presence of particles in the gullet and mouth of some of these animals would also appear to indicate the loss of the stomach contents at death.

From the beginning of 1961, rough counts of the numbers of nematode worms found in the stomachs were also recorded. Of the 236 grey seals dealt with in this way only 23 of the smaller animals were not infested, 73 contained fewer than 100 worms, and the remaining 150 from 100 to 1500. The average number of nematodes in the 236 grey seals so examined was 196.

Out of 116 common seal stomachs examined for nematodes, 46 were not infested; these included all the eleven unweaned pups but also a number of well-grown animals of up to 58 inches. Twenty-two common seals contained fewer than 10 worms each, 44 carried from 10 to 80 each and only four stomachs contained 100 worms or more, the highest total, 450, being found in the stomach of a male of 62 inches. The average worm load in the stomachs of the 116 common seals was 20.

The worms from both species of seal were identified as belonging to at least three genera, *Porrocaecum* (= *Phocanema* = *Terranova*), *Contracaecum* and *Anisakis* and included different stages from the larvae to the adults. These identifications have since been confirmed by van Thiel (1966, page 316).

TABLE IV

LENGTHS OF SEALS EXAMINED AT THE MARINE LABORATORY AND THE MEANS BY WHICH THEY WERE PROCURED
1958–1966

Length inches	(cm)	Grey Seals: Salmon Gears Bag-nets	Grey Seals: Salmon Gears Stake-nets	Grey Seals: Salmon Gears Drift-nets	Grey Seals: White-fish Gears Cod-nets	Grey Seals: White-fish Gears Seine and trawl	Grey Seals: White-fish Gears Hook and line	Grey Seals: Shot in water or on beach	Grey Seals: Totals	Common Seals: Salmon Gears Bag-nets	Common Seals: Salmon Gears Stake-nets	Common Seals: White-fish Gears Cod-nets	Common Seals: Shot in water or on beach	Common Seals: Totals
36	(91)	—	—	—	—	—	—	1	1	—	2	—	—	2
37		—	—	—	—	—	—	—	—	1	2	—	1	4
38		—	—	—	—	—	—	1	1	3	—	—	—	3
39		2	—	—	—	—	—	3	5	1	2	—	3	6
40	(102)	3	—	—	—	—	—	8	11	—	—	—	3	3
41		3	—	—	—	—	—	3	6	2	—	—	10	12
42		3	—	—	3	—	—	1	7	—	1	—	6	7
43		3	—	—	2	—	—	6	11	1	—	1	13	15
44		8	2	—	2	—	—	2	14	1	1	—	13	15
45	(114)	5	2	—	1	—	—	2	10	1	—	—	18	19
46		5	2	—	2	—	—	4	13	—	—	—	15	15
47		9	2	—	6	—	1	4	22	2	—	—	12	14
48		7	—	—	1	—	—	4	12	—	—	—	3	3
49		9	—	—	3	1	1	4	18	—	—	—	5	5
50	(127)	5	1	1	3	—	—	2	12	—	—	—	5	5
51		6	1	—	1	—	1	2	11	1	—	—	1	2
52		6	2	1	3	—	—	4	16	—	—	—	3	3
53		3	1	—	1	—	—	3	8	1	—	—	—	1
54		2	3	—	—	—	—	3	8	1	—	—	3	4
55	(140)	1	1	—	—	—	—	4	6	—	—	—	1	1
56		1	1	—	—	—	—	3	5	—	—	—	1	1
57		4	1	1	1	1	—	—	8	—	—	—	1	1
58		2	—	—	—	—	—	2	4	—	—	—	1	1
59		—	1	—	—	—	—	3	4	—	—	1	2	3
60	(152)	1	2	—	—	—	—	2	5	—	—	—	4	4
61		1	2	—	—	—	—	3	6	—	—	—	—	—
62		3	2	—	—	—	—	2	7	—	—	—	1	1
63		2	2	—	—	—	—	2	6	—	—	—	1	1
64		2	1	—	—	—	—	3	6	—	—	—	2	2
65	(165)	1	2	—	2	—	—	2	7	—	—	—	3	3
66		1	2	—	—	—	—	3	6	—	—	—	1	1
67		—	1	—	—	—	—	2	3	—	—	—	2	2
68		1	2	—	—	—	—	1	4	—	—	—	2	2
69		2	—	—	—	—	—	1	3	—	—	—	1	1
70	(178)	—	2	—	—	—	—	2	4	—	—	—	1	1
71		—	1	—	—	—	—	2	3	1	—	—	1	2
72		1	—	—	—	—	—	1	2	—	—	—	1	1
73–97	(—246)	4	8	—	—	1	—	26	39	—	—	—	—	—
? size		2	—	—	—	—	—	6	8	1	—	—	8	9
Totals		108	47	3	31	3	3	127	322	17	8	2	148	175

During the examination of the stomach contents it was evident that some of the parasitic worms had succeeded in escaping from the stomach mainly into the oesophagus and mouth, so that the numbers in the preceding paragraphs are probably less than the numbers present at the time the seals were killed. Nevertheless the counts recorded may be regarded as adequate for comparative purposes.

TABLE V

THE FOOD OF THE GREY SEAL ON THE SCOTTISH MAINLAND

	Seals killed in (a) Salmon nets		(b) White Fish Gear		(c) Sea or on Beaches		Totals	
No. examined	158		37		127		322	
No. empty	59(37·3%)		11(29·7%)		76(59·8%)		146(45·3%)	
No. with recognisable food	99(62·7%)		26(70·3%)		51(40·2%)		176(54·7%)	
No. feeding on		%		%		%		%
FISH	92	92·9	22	84·6	45	88·2	159	90·3
Salmonids	35	35·4	1	3·8	16	31·4	52	29·5
Salmon, *Salmo salar*	31	31·3	1	3·8	14	27·5	46	26·1
Sea trout, *S. trutta*	1	1·0	—	—	1	2·0	2	1·1
Gadoids	47	47·5	18	69·2	18	35·3	83	47·2
Cod, *Gadus callarias*	20	20·2	10	38·5	8	15·7	38	21·6
Haddock, *G. aeglefinus*	5	5·1	1	3·8	1	2·0	7	4·0
Whiting, *G. merlangus*	11	11·1	1	3·8	3	5·9	15	8·5
Saithe, *G. virens*	12	12·1	2	7·7	3	5·9	17	9·7
Ling, *Molva molva*	—	—	1	3·8	—	—	1	0·6
Clupeoids	2	2·0	—	—	5	9·8	7	4·0
Herring, *Clupea harengus*	—	—	—	—	3	5·9	3	1·7
Sprat, *C. sprattus*	—	—	—	—	2	3·9	2	1·1
Pleuronectids	4	4·0	2	7·7	2	3·9	8	4·5
Plaice, *Pleuronectes platessa*	3	3·0	1	3·8	1	2·0	5	2·8
Conger eel, *Conger conger*	—	—	1	3·8	1	2·0	2	1·1
Common eel, *Anguilla anguilla*	2	2·0	—	—	—	—	2	1·1
Skate, incl. ova, *Raia* sp.	3	3·0	—	—	2	3·9	5	2·8
Sand eel, *Ammodytes* sp.	—	—	—	—	1	2·0	1	0·6
Grey mullet, *Mugil* sp.	—	—	—	—	1	2·0	1	0·6
Blenny, *Zoarces viviparus*	—	—	—	—	2	3·9	2	1·1
Blenny, *Blennius* sp.	—	—	1	3·8	—	—	1	0·6
Angler, *Lophius piscatorius*	—	—	—	—	1	2·0	1	0·6
Lumpsucker, *Cyclopterus lumpus*	1	1·0	—	—	1	2·0	2	1·1
Black scabbard-fish, *Aphanopus carbo*	—	—	—	—	1	2·0	1	0·6
MOLLUSCS	13	13·1	4	15·4	9	17·6	26	14·8
Celphalopods	11	11·1	3	11·5	7	13·7	21	11·9
Squids	3	3·0	—	—	2	3·9	5	2·8
Octopods	1	1·0	—	—	—	—	1	0·6
Mussels	1	1·0	—	—	1	2·0	2	1·1
Gasteropods	1	1·0	1	3·8	2	3·9	4	2·3
Buccinum	1	1·0	—	—	—	—	1	0·6
CRUSTACEANS	6	6·1	9	34·6	8	15·7	23	13·1
Crabs	4	4·0	2	7·7	6	11·8	12	6·8
Cancer pagurus	—	—	1	3·8	1	2·0	2	1·1
Carcinus	—	—	—	—	1	2·0	1	0·6
Hyas	—	—	—	—	1	2·0	1	0·6
Portunus	—	—	1	3·8	1	2·0	2	1·1
Galathea	—	—	1	3·8	—	—	1	0·6
Eupagurus	3	3·0	—	—	1	2·0	4	2·3
Shrimps, *Pandalus, Crangon*	1	1·0	5	19·2	1	2·0	7	4·0
Norway lobsters, *Nephrops*	—	—	1	3·8	1	2·0	2	1·1

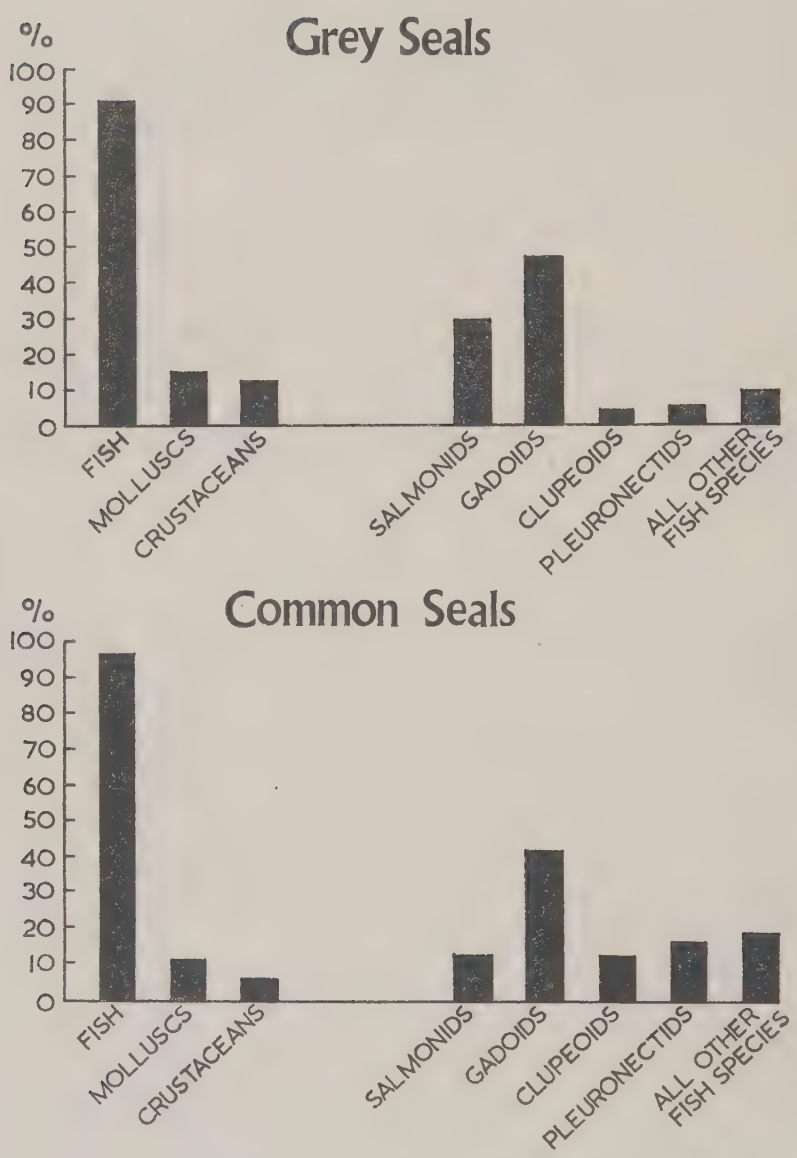

Fig. 2. Frequency of occurrence of the principal types and subtypes in the food of seals on the Scottish mainland.

THE FOOD OF GREY SEALS

The analysis of the stomach contents of grey seals from the Scottish mainland is summarised in Table V. Fish or fish remains were identified in 90% of the stomachs containing recognisable food and thus must be regarded as the commonest item in the diet of this seal. The frequency of occurrence of the various subtypes in the stomachs show that two families of fishes, the Salmonidae (in 30%) and the Gadidae (in 47%) were eaten more commonly than any of the other familes represented in the food, although Clupeidae and Pleuronectidae were also fairly prominent and indeed may be of even greater importance locally (Fig. 2). Among the individual species preyed upon the salmon (in 26%) and the cod (in 22%) outnumber all others, while three other gadoids, saithe, whiting and haddock, were each eaten fairly frequently by 4 to 10% of the seals. In all, at least twenty different species of fish were identified in the food, and of these only three, the blenny, the viviparous blenny and the black scabbard-fish, may be considered of no economic importance. The record of the

black scabbard-fish found in the stomach of a grey seal killed on Oronsay on the west coast of Scotland is rather extraordinary, since this southern species is a rare visitor to coastal waters on the west of Scotland. Fish such as sand eels and lumpsuckers can no longer be regarded as having no commercial importance following the development of industrial fisheries for the sand eel and the utilisation of the roe of the lumpsucker in the manufacture of mock caviare.

In addition to fish, grey seals also eat various types of molluscs and crustaceans, but these types were identified in only 15% and 13% of the stomachs respectively, so that they are of little importance compared with fish. Of the subtypes, the remains of cephalopods (squids and octopods) occurred in 12% of the stomachs and crab remains, including a variety of genera, in 7%. No direct evidence was found in these studies of grey seals preying on the common lobster although fishermen in various parts of the British Isles and in Canada have from time to time reported interference with creels by seals. The records of the Marine Laboratory include two instances of young grey seals having died by entering lobster pots, but in these and other examples of interference it is not possible to decide whether the attraction was the fish bait or the lobsters or crabs caught.

Although molluscs and crustaceans, from their frequency of occurrence in the stomachs, may appear to form an appreciable part of the food of seals, their combined volumes are estimated to form a much smaller proportion of the total stomach contents. This is based to some extent on the relatively small size of the invertebrates eaten compared with the fish, and also by the fact that these organisms are often represented in the stomachs by mere traces—for example by the jaws of cephalopods, the opercula of gasteropods and the claws of crabs—possibly in some instances as relics of earlier meals.

Although it is known that young grey seals commence feeding by taking these invertebrates, it is not certain that the older animals continue to feed regularly on them. Each of the molluscan and crustacean types represented in Table V is also eaten by fish, particularly by cod and codling, so that seals could also acquire them by eating these fish. Furthermore, it is known from studies of the food of fishes that certain indigestible parts, such as cephalopod jaws, crab claws and gasteropod opercula, tend to be retained in the stomachs after the digestion of the remainder of the food and may even be retained after more than one meal. Consequently, caution is required in reaching conclusions on the relative frequency or value of the different food items. The occurrence of cephalopod jaws alone in nine of the 21 seal stomachs regarded as containing cephalopods might suggest a similar retention of the durable parts by seals, so that the frequency figures for molluscs and crustaceans in Table V may over-stress the importance of these types.

Comparison of the Food of Grey Seals from Different Sources

It has very reasonably been suggested that the various means by which the seal carcases were obtained for examination (Table IV) may have some effect on the results of the food analysis. Doubtless this is so, at least to some extent. In order to test this the stomach contents in Table V have been arranged in three groups—seals obtained from salmon nets, those obtained from white fish gear and those shot in the water or on beaches away from nets and including those killed at times when salmon fishing is suspended. Fish are shown to occur predominantly in all three categories (85 to 93%) with molluscs and crustaceans in each case playing a less important role. Indeed, apart from the scarcity of salmonid records in the stomachs of seals drowned in cod-nets, the composition of the food in all three categories is remarkably similar. Salmon and cod represent the commonest individual species eaten, both by seals caught in salmon nets and by those killed in the sea or on beaches. These results are of particular interest in that they seem to refute the assertion by some critics that the consideration of the stomach contents of seals caught in salmon nets gives a biased impression of the importance of salmon in the diet of these animals.

Cod is the outstanding food of seals obtained from white fish fisheries; this is to be expected since most of the seals in this category were drowned in cod-nets and, therefore, it is perhaps not surprising that only one of the 26 seals containing recognisable food in this category was found to have eaten salmon. As salmon fishing is mainly a coastal operation and as fishing for white fish is carried on at varying distances offshore, it might be argued that the food of seals in coastal waters differs from that in offshore waters and that if more seals were examined from offshore grounds the emphasis on the importance of salmon in the diet of seals might be diminished. This point of view can, however, be countered by two observations:—

(1) that the main concentration of seals is apparently in coastal waters and that their distribution becomes sparser as one proceeds further offshore;

(2) that seal predation on salmon is not confined to purely coastal waters and has been experienced offshore to a distance of at least 10 miles (Rae and Shearer, 1965, p. 26).

At this point it is appropriate to consider in more detail grey seals killed in the open sea and on beaches at a distance of five miles or more from the nearest salmon nets. During the salmon fishing season (February to September) among seals killed five miles or more from the nets, seven out of eighteen containing recognisable food were found to have been feeding on salmon. Among those killed less than five miles from the nets, twelve out of 29 containing recognisable food were feeding on salmon. These observations suggest that the numbers of grey seals feeding on salmon five miles or more from the nearest nets are not significantly different from those preying on salmon less than five miles from nets.

Seasonal Differences

Of 54 non-breeding grey seals examined from 1st October to 31st January (the close season for salmon fishing), 25 (46%) contained recognisable food, and of these 16 contained fish or fish remains, while 12 had eaten small decapod crustaceans and 7 revealed traces of molluscs in the form of jaws and opercula. The fish identified in these stomachs included herring, haddock, cod, saithe, some unidentified gadoids and a blenny. No trace of salmonids was found in these stomachs, although salmon were identified in the stomachs of seals from the beginning of February to the end of August, and salmon are known to be "running" during the close season. This might be regarded as indicating a seasonal trend in seal predation on salmon, although confirmation is prevented by the absence of salmon nets on the coast. Moreover, the numbers feeding on fish from October to January, 16 (64%), and the numbers on small decapod crustaceans, 12 (48%), also suggest a possible change in the feeding compared with the rest of the year. However, it must be pointed out that a fairly high proportion of the seals examined from October to January were young animals, some of them apparently direct from the breeding grounds, and these, it is generally agreed, begin feeding by the capture of shrimps and other small crustaceans.

Although none of the seals examined during the close season appeared to have been eating salmon, it must not be assumed that seals never prey on salmon at this time; on the contrary, the evidence of freshly clawed fish entering the North Esk river from October 1963 to February 1964 clearly suggests that predation on salmon continues throughout the winter, when salmon fishing is suspended (Rae and Shearer, 1965, page 25). The difference in the incidence of salmon in the seal food may rather indicate the effect of nets during the fishing season in rendering salmon more vulnerable to seals.

Quantitative Examination of the Stomach Contents

It has already been observed that relatively few of the stomachs examined contained an appreciable amount of food. This could well be largely owing to the total or partial loss of the stomach contents by regurgitation when the seals find themselves trapped. It is also evident from the soup-like consistency of the contents of many seal stomachs that digestion of the food is fairly rapid so that analysis of the quantities of the various types of food is often impossible. However, throughout these investigations it has occasionally been possible to distinguish and measure the main components of the stomach contents of certain seals, usually in the form of chunks of flesh as they were bitten and swallowed. Of 25 stomachs containing appreciable amounts of food which could be identified and quantified, 17 contained from 9·5 oz to 7 lb (276–3178 g) of salmonid flesh (mostly salmon) giving a total of 51·7 lb (23614 g). Eight stomachs contained from 0·5 to 3·9 lb (227–1816 g) of gadoid and/or flat fish remains with a total of 19·4 lb (8853 g) and one stomach contained 10·2 lb (4653 g) consisting entirely of young herring. One of these stomachs contained a mixture of 5 lb (2270 g) of salmon and 0·5 lb (227 g) of gadoid remains.

These weights do not provide any conclusive results but they would seem to suggest that salmonids (mainly salmon) and gadoids (mainly cod) not only appear more frequently than other types but also constitute the outstanding items on a quantitative basis in the food of grey seals on the Scottish mainland.

Circumstantial Evidence

At this point it is pertinent to refer to reports of seals found in salmon nets along with partly eaten salmon. Because the stomachs of some of these seals were found to contain no trace of salmon, the presence of both seals and mutilated fish in the net is not regarded by everyone as conclusive evidence that the seal killed and ate the salmon. In this connection certain observations made during the present investigations may be summarised as follows:—

1. Eight seals with empty stomachs were killed in bagnets in which partly eaten salmon or sea trout were also found.
2. Fourteen seals with salmon in their stomachs were killed in bagnets in which partly eaten salmon were also found.
3. Three seals with cod and other gadoid remains in their stomachs were found in nets along with the remains of grilse and salmon.
4. One seal found alive in a bagnet was observed to vomit most of its meal as the fishermen approached the net; the remaining contents of its stomach included cod.
5. Yet another seal similarly trapped was seen to throw up a grilse as it was hauled on board the coble, while the remains of two more grilse were found in the stomach contents.
6. On three occasions seals were found in nets along with salmon, which were mutilated, and other fish (flounders and lumpsuckers) all of which were intact.
7. On one occasion a seal with no food in its stomach was taken from a net which also contained a salmon and a lumpsucker, both partly eaten.

Some of these observations clearly show that grey seals eat salmon which have been caught in nets. Others suggest that, although no salmon may be found in the stomachs of certain animals, the suspicion that these have eaten salmon in the nets cannot be entirely disregarded. The observations also provide further evidence that seals throw up part or all of their stomach contents on finding themselves trapped in nets. All things considered it may well be that the numbers of grey seals eating salmon in and around salmon nets on the Scottish coast are greater than the available evidence of the presence of salmon in the seals' stomachs indicates. The last two observations also show that seals may eat species trapped in the nets other than salmon but the records under item 6 would seem to support the view previously expressed (Rae, 1960), that seals sometimes show a preference for salmon.

Regional Differences in the Food

The seals considered so far were obtained almost entirely from the Scottish mainland (Table I) and especially from the east coast from Fife to Caithness. The east coast of Scotland, from the Tweed to Duncansby Head in Caithness provides about 80% of the Scottish salmon catch. Consequently it might be claimed that seal stomachs from this area are liable to give a biased impression of the food of these animals. This is fair comment and so it is essential to examine the food in areas where salmon are less plentiful.

The remaining 20% of the Scottish salmon catch is obtained from districts on the north and west coasts, including the Outer Hebrides. Only 19 grey seals have been examined from these coasts and of these 14 contained recognisable food. All had preyed on fish—seven on salmonids (including five on salmon), five on gadoids (including two on saithe and one on whiting), four on plaice, one on skate, one on common eel and one on cephalopod. As far as they go these results suggest that the food of grey seals to the north and west of Scotland is not significantly different from that on the east coast, and that all the results from the Scottish mainland may conveniently be combined as in Table V.

It is generally agreed that salmon are scarcer round Orkney and Shetland than elsewhere in Scotland although sea trout are plentiful in both groups of islands. It is therefore of interest to consider the food of grey seals in these two areas as they would appear to come nearest to satisfying the conditions referred to above.

Orkney

Stomachs of adult grey seals killed on the Orkney breeding colonies from mid-October to the beginning of December in 1959, 1960 and 1961, were found to contain no recognisable food. This agrees with the generally accepted view that adult grey seals stop feeding during their breeding season. The stomach contents of 19 grey seals shot at or near certain breeding colonies in Orkney by Mr E. A. Smith of the Nature Conservancy, at other times of the year, have been examined at the Marine Laboratory. The results, summarised in Table VI, show that in Orkney, as on the Scottish mainland, fish is a prime food of grey seals. At least twelve different species were identified in the food, in which gadoids were the prominent group. Not unexpectedly, salmon was not identified in the food, although sea trout remains were found in one stomach. In addition, however, the Orkney stomachs included a greater representation of cephalopods, both numerically and volumetrically, than those obtained on the Scottish mainland, although in four of the fourteen records the cephalopods were represented by jaws only. The species of cephalopods eaten by seals included the squid *Loligo* (probably *L. forbesii*) and the much rarer (in Scottish waters) *Todarodes sagittus* and the octopod *Eledone cirrhosa*. The presence of *Eledone* in a number of stomachs is particularly interesting since his animal can scarcely be regarded as common in Scottish waters as a whole.

TABLE VI

THE FOOD OF GREY SEALS IN ORKNEY AND SHETLAND

(from stomach contents provided by Mr E. A. Smith of the Nature Conservancy)

	Orkney 1961–62	Shetland 1963
No. containing recognisable food	19	27
No. feeding on		
Fish	16	26
Salmonids	1	1
Sea trout, *Salmo trutta*	1	1
Gadoids	7	9
Cod, *Gadus callarias*	3	1
Haddock, *G. aeglefinus*	1	—
Whiting, *G. merlangus*	1	3
Saithe, *G. virens*	2	1
Clupeoids	—	1
Herring, *Clupea harengus*	—	1
Pleuronectids	2	—
Skate, *Raia* sp.	2	—
Sand eels, *Ammodytes* sp.	1	22
Sea scorpion, *Cottus scorpius*	1	1
Lumpsucker, *Cyclopterus lumpus*	1	1
Rockling, *Onos* sp.	1	—
Gunnel, *Pholis gunnellus*	2	—
Molluscs	14	5
Cephalopods	14	3
Eldone cirrhosa	4	—
Loligo sp.	2	—
Todarodes saggitatus	2	—
Gasteropods	—	2
Crustaceans	2	1
Crabs	2	1
Hyas sp.	—	1
Munida sp.	—	1
Ascidians	1	—

Plate I

Cod mutilated by seals in cod-nets off Kincardineshire, February 1966; some of these fish were discarded, others sold at reduced prices.

Shetland

The stomach contents of 27 grey seals killed by a hunter in the vicinity of Fitful Head, south-west Shetland, have also been made available by the Nature Conservancy for examination at Aberdeen. The results, also given in Table VI, once more stress the importance of fish in the diet of these animals. At least eight species of fish were identified in the stomach contents, including sea trout, but, unlike any of the other localities where the food of seals has been investigated, the principal food type numerically proved to be sand eels. It is remarkable that, prior to the examination of the seal stomachs from Shetland, sand eel remains were found in only two grey seals, one from Orkney and the other from the Firth of Tay. It should perhaps be mentioned that the identification of the sand eels in some of the Shetland stomachs was based on the presence of their otoliths in a mass of unidentifiable fish flesh. Furthermore, it should be noted that seals rarely, if ever, ingest the heads of large fish, thus eliminating the possibility of their identification from otoliths. Sand eels are a major food item for many species of fish, which are in turn preyed upon by seals. It is known from an examination of the food of cod (Rae, 1967) that dense concentrations of sand eels occur every spring and summer off south-west Shetland, so that predation by seals on this species would seem to be a natural consequence.

Although these studies of the food of grey seals in Orkney and Shetland reveal obvious differences when compared with similar studies from the Scottish mainland, such differences are more in the proportions of the various types than in the types themselves. It should also be stressed that the sampling of seals in both Orkney and Shetland was very local and in neither instance truly representative of the two groups of islands. It is important, therefore, not to over-stress any apparent differences in the food of the local seals arising from features of the local fish and invertebrate populations; it is possible that a more widespread sampling in the Orkneys and Shetlands, both in time and in space, might well give different results from those summarised in Table VI. This possibility would seem to be stressed by reports from Orcadians and Shetlanders of seals observed killing and eating sea trout near the mouths of streams in different parts of the islands. A reliable and experienced seal hunter in the Orkneys claims to have found every species of native fish, with the exception of dogfish, in seals' stomachs, including both salmon and sea trout.

Evidence from Commercial Sources

Evidence of predation by grey seals on fish has also been obtained from reports by fishermen and fishery officers. Logs kept by foremen at salmon fishing stations on the Scottish east coast from 1959 to 1966 enumerate 1088 occasions on which seals were observed killing and eating salmon (Rae and Shearer, 1965).

Another fishery which suffers from seal activity is the winter and spring cod-net fishery on the Angus and Kincardine coasts. In this fishery cod, as they hang gilled in the set nets, are the main target for seals. The damage caused varies from year to year, but it seems to have been greatest in the winter of 1965 to 1966, when many fishermen suffered considerable losses through having to discard variable proportions, up to 25%, of their catches as unmarketable, and by having to accept lower prices for other fish mutilated by seals but still marketable (Plate I). On rare occasions even greater losses have been experienced—for example—in one catch of eight boxes on 18th February, 1966, five boxes of fish had to be thrown overboard as unmarketable.

A somewhat similar fishery with ground-nets in the Minch, during the winter and spring, also suffers from seal activity. In this fishery cod, saithe, lythe and hake are often eaten, or partly eaten, by seals—a common feature being the removal of the belly region of the fish, including the ripe gonads and liver. Mutilated specimens of each of these species of fish from this source have been examined and identified at the Marine Laboratory.

Evidence of predation by grey seals on young herring and sprats has been obtained from fishermen operating ring-nets in the Firth of Forth.

Apart from these seasonal losses experienced in varying proportions every year, reports have, from time to time, been received from fishermen of seals observed killing and eating other marine fish, including haddock, flatfishes, ling and skate, in the vicinity of trawlers and seiners as their nets are being hauled. Small and hand-line fishermen on different parts of the Scottish and English coasts also complain from time to time of seals stripping fish from their hooks during hauling operations. Finally, there is some evidence from Scottish, Welsh, and Canadian sources that grey seals also eat lobsters, although two grey seals found dead in lobster creels at Eyemouth and in Orkney, may possibly have been trying to eat the bait.

THE FOOD OF COMMON SEALS

The analyses of the stomach contents of common seals are summarised in Table VII. The high proportion of empty stomachs (57%) is again evident, while the proportion containing recognisable food other than milk, 37%, is considerably smaller than in the grey seal. Although these results on the whole resemble those for the grey seal, some differences are apparent in the detailed analysis. It would appear that the common seal preys less frequently on salmon and cod but more frequently on whiting, saithe, herring and flatfishes (mainly plaice) than the grey seal. The diet of the common seal would also seem to include more estuarine species such as the viviparous blenny (Fig. 2).

In general, too, the fish eaten by the common seal are smaller than those eaten by the grey seal, which is the larger of the two species. However, the smaller average size of the fish and the slightly higher proportion of non-commercial species in the food of the common seal would appear to be owing in some measure to the smaller average size of the animals, as well as to their estuarine habitat. These differences may also be linked with the distribution of the two species of seal and with the distribution of the fish preyed upon.

Although the present investigation, mainly based on material from the Scottish east coast and largely from one locality, the outer Firth of Tay, has revealed relatively few salmonids in the stomachs of common seals, evidence from other sources suggests that predation by this species on salmon may at times be considerably greater in some river mouths.

TABLE VII

THE FOOD OF THE COMMON SEAL

No. examined	175	
No. empty	100	(57·1%)
No. containing milk	11	
No. with other recognisable food	64	(36·6%)
No. and percentage feeding on:—		
FISH	62	96·9%
Salmonids	8	12·5%
Salmon, *Salmo salar*	5	7·8%
Sea trout, *S. trutta*	2	3·1%
Gadoids	26	40·6%
Cod, *Gadus callarias*	2	3·1%
Haddock, *G. aeglefinus*	3	4·7%
Whiting, *G. merlangus*	10	15·6%
Saithe, *G. virens*	11	17·2%
Clupeoids	8	12·5%
Herring, *Clupea harengus*	1	1·6%
Pleuronectids	11	17·2%
Plaice, *Pleuronectes platessa*	6	9·4%
Common dab, *Limanda limanda*	1	1·6%
Mackerel, *Scomber scombrus*	1	1·6%
Horse mackerel, *Trachurus trachurus*	1	1·6%
Blenny, *Zoarces viviparus*	6	9·4%
Common eel, *Anguilla anguilla*	1	1·6%
Sand eels, *Ammodytes* sp.	3	4·7%
MOLLUSCS	7	10·9%
Mussels (*Mytilus*)	4	6·3%
Squid	1	1·6%
CRUSTACEANS	4	6·3%
Crabs	3	4·7%
Carcinus	2	3·1%
Eupagurus	1	1·6%
Portunus	1	1·6%
POLYCHAETES	1	1·6%

These observations have been supplemented by records of the contents of the stomachs of common seals killed by student hunters in the Dornoch Firth during the summers of 1956 and 1960. In all, 30 common seals, most of them adults, and all shot at some distance from fishing stations, were examined; all except four contained food, mostly fish, but including traces of crustaceans and molluscs. Twenty-one stomachs contained pieces of salmon flesh but no head bones; three contained a pinkish fluid suggestive of salmonids, and in two the contents were unrecognisable. Evidence of the common seal preying on salmon or sea trout has also been obtained from the mouth of the River Findhorn and from the Ayrshire and Argyllshire coasts, and, at various times, naturalists have referred to the predatory habits of this animal on salmon at river mouths (Millais, 1906; Berry, 1935; Darling, 1947).

DISCUSSION ON THE FOOD OF SEALS

Popular works on seals frequently stress the relative unimportance of the fish and invertebrates composing the food of these animals. However, until the current Scottish investigation of the food was commenced in 1958 and the preliminary results were published in 1960, no detailed study of the food of the grey seal had been attempted in this country or in Europe, while accounts of the food of the common seal were based mainly on investigations carried out in the southern North Sea (Nehring, 1886; Havinga, 1933; Sergeant, 1951). Statements that the grey seal's diet includes "rock fish, saithe, pollack, lythe, halibut, lumpsucker, ling, salmon, herring, conger eel, flounder and other flatfish . . . some crustaceans and molluscs, including the common mussel and the bivalve *Lutraria elliptica*" (King, 1964), while literally correct, if the vague term "rock fish" is intended to signify wrasse and it is borne in mind that pollack and lythe are the same fish, are nevertheless apt to give a false impression of the animal's feeding habits. Reliable conclusions in regard to the relative importance of the various food items must be based on sampling as representative, both in time and place, as is reasonably possible. Furthermore the distribution of both predator and prey, including the availability of the latter, throughout the year must also be considered. The sampling of the seal stomachs in this investigation has already been described on pages 5 to 8.

The Distribution of Grey Seals

The general distribution of grey seals on the Scottish coast has been described by a number of authorities (Report of Consultative Committee, 1963; Boyd, 1963). Their conclusions may be summarised thus:—

Northwest and west of Scotland	17000
Shetland	3000
Orkney	10000

In addition the latest estimate of the total grey seal population of the Farne Islands, based on a pup production of 1722 in 1966, is 6,000. More than half of these may be expected, on the basis of tagging experiments on the young, to move northwards along the Scottish coast to feed. This indicates that the total number of grey seals feeding mainly in Scottish waters is in the region of 33,000.

Tagging experiments have shown that yearling grey seals tend to scatter on leaving the colonies where they are born and small numbers from the Farne Islands and other colonies have been recovered from continental shores. Similar experiments in the Orkneys in 1961 and 1962 resulted in somewhat greater numbers of recoveries from the Norwegian coast (Hickling, Rasmussen and Smith 1962; Smith 1963), but there is no evidence from any of the countries bordering the North Sea, from Faroe or from Iceland of any great movement of seals to their shores at any time. Øynes (1964) stated that the grey seal population of Norway declined to a minimum in 1956; from that year onwards numbers of this species began to reach Norway from Great Britain, the increase being most noticeable in the central part of the Norwegian coast, and in 1963 he estimated the total grey seal population of Norway at between 2,000 and 3,000. Considering that "the grey seal is not much persecuted by hunters" in Norway, this total cannot be regarded as indicating mass immigration of grey seals from the United Kingdom.

The increase in the numbers of the grey seal in Scottish waters is evident in the counts of young born on the established breeding colonies, in the extension of breeding to new colonies and in the resumption of breeding on former colonies which had long been deserted. In recent years, too, reports by fishermen and hunters of the hauling out of grey seals throughout the summer in many localities on the Scottish coasts, particularly the west coast and the islands have been confirmed by members of the Marine Laboratory staff and others. These concentrations are individually considerably smaller than the breeding concentrations but counts of up to 100 seals have been recorded in some places in northwest Scotland. In general, however, the distribution of the grey seal, from spring to early autumn, is more scattered than during the breeding season in the last four months of the year.

Of special interest is the extension of the grey seal distribution to areas hitherto believed to be typical common seal territories. Reference has already been made to this development in the Orkney Isles and in the Firth of Forth (Rae, 1960). On this occasion, however, attention is focussed particularly on the occupation of sand banks by assemblies of grey seals, a feature which Craggs and Ellison (1960) rightly regard as previously extremely rare. In addition to the concentrations of up to 100 or more of this seal on sand banks in the estuary of the Welsh Dee, non-breeding colonies of grey seals have recently become established on similar banks on the Dornoch Firth, in the Firth of Tay and on the Scroby Sands near Yarmouth, and the last locality is now even the site of a small breeding colony. This extension of the hauling-out grounds, including a change in the nature of the grounds selected for that purpose, seems in itself to accord with the evidence of an increase in the stocks.

If, as seems likely, many grey seals follow a somewhat scattered existence throughout their adolescence and on reaching maturity, outside the breeding season, their distribution must be considered in relation to the extent of the Scottish coastline. In Scotland, including the Shetlands, Orkneys and Western Isles, it has been calculated that there are 5,300 miles of coastline (Booth, 1961). Assuming the resident Scottish population of grey seals to be 30,000, this would mean an average of fewer than 6 seals per mile of coastline. However, as summer concentrations of grey seals of up to 100 or more are known to occur in the least accessible parts, for example, northwest Scotland and the outer Isles, the number per mile of coastline in the more populous parts of the country is likely to be much less. Furthermore, grey seals frequently spend a considerable time hauled out in inaccessible places and are able to sleep submerged in the sea, only coming to the surface at intervals to breathe (Lockley, 1954), and although they are mainly coastal in habit they may occasionally be found some distance offshore. It follows, therefore, that the chances of seals being readily observed from the shore are relatively small. Consequently there is no strong reason for assuming the departure of large numbers of seals from British waters because observers have failed to locate them or have found them to be scarce in certain areas.

Are Seals Significantly Pelagic?

Because all the grey seals examined in these Scottish investigations were obtained from coastal waters (most of them from within one mile of the shore) it has been suggested that their coastal origin may give a biased impression of the food, particularly if the seals at any time lead an extensive pelagic existence.

Observations from research vessels in the North Sea, in the Faroe/Shetland Channel and on the west of Scotland over the past thirty years, while resulting in numerous sightings of sharks, whales, porpoises, dolphins and even rare fishes, such as the sunfish, have failed to reveal the presence of seals at a distance of more than 20 miles from the nearest land. Enquiries among marine fishermen by the author personally and by fishery officers have elicited information which suggests that the main concentrations of grey seals are within territorial waters. Reports of such concentrations around fishing vessels in the Firth of Forth, on the Berwickshire coast, in the Moray Firth and elsewhere help to confirm this. Occasionally, grey seals are known to appear singly or even in small groups of two or three alongside fishing vessels, at a distance of 10 miles from the shore, but beyond this such records are very infrequent and seals have rarely, if ever, been seen by fishermen more than 20 miles offshore. Records of grey seals caught in fishing gear have mainly been obtained from coastal waters. A few young tagged grey seals have been recovered from fishing vessels operating 20 miles or more from land, but some of these were dead when found and may have been carried offshore by wind or currents.

The movement of young grey seals from British breeding colonies to continental shores has already been mentioned (Telfer & Watt, 1953; Hickling, 1957, 1959; Coulson and Hickling, 1960 a, 1962, 1963; Hickling, Rasmussen and Smith, 1962; Boyd, 1962; Boyd and Laws, 1962). The dispersal of tagged seals from the Farne Islands northwards to the Scottish coast and southwards along the English coast seems to emphasise the coastal habit and movement of these animals. The recovery of grey seals from countries bordering the North Sea might seem at first to indicate a possible direct movement from the Farnes. The numbers returned, however—8 from Holland, 4 from Germany and 2 from Denmark, the numbers thinning out with distance from their place of origin—rather suggest a coastal migratory movement round the shores of the southern North Sea. Moreover, the records of one seal from the Farnes (No. 6217 (Coulson and Hickling, 1962) recovered first from Essex and later from North Holland would seem to support this view.

At the same time it is clear from Norwegian recoveries of seals tagged on the Farne Islands and in Orkney that some young grey seals are capable of crossing the North Sea, but whether these crossings are purposeful or merely accidental, owing to offshore winds, is not known. Seals from the Farne Islands may possibly have followed the Scottish coast northwards to Buchan Ness and then have turned or been carried eastwards, as one animal (No. 5412) subsequently recovered from Norway was previously identified at the entrance to the Firth of Forth (Coulson and Hickling, 1960 b). In some instances the short interval of time between their tagging and their recovery abroad suggests a remarkably rapid crossing of the intervening sea.

Even more impressive, however, is the recovery of a tagged seal in Faroe less than two months after its liberation on the Farne Islands (Hickling, 1957). Although this animal was dead when found, it demonstrates the ability of young grey seals to cross water as deep as the Faroe-Shetland Channel in a relatively short time.

From this review of the available information on the subject there is no evidence to suggest that grey seals lead a prolonged pelagic existence outside coastal waters. Although some are known to have crossed extensive areas of sea, they would seem, from the records of tagging experiments and from the failure of fishermen and research workers to observe seals at sea beyond the twenty miles limit, to have done so relatively quickly.

The habit of seals in hauling out on rocks, beaches and sand banks to rest also suggests the unlikelihood of any extensive pelagic life, even although it is recognised that individual animals can apparently live at sea for some time without coming ashore. Another feature of seals' behaviour which would appear to be against any significant pelagic existence is the manner in which they make use of natural or artificial barriers in the water while hunting (Rae, 1960). The scarcity of such barriers in the open sea, apart from the sea bottom, would seem to diminish their ability to hunt successfully.

Although seals have from time to time been recorded as having reached or as having been caught at certain depths—Harrison (1960) refers to a grey seal caught on a hook at a depth of 146 metres—it seems reasonable to assume that they would find feeding more difficult in the deeper water away from land. Furthermore, the capture of a seal on a hook or in a trawl fishing at a particular depth is not a reliable indication that the seal was caught at that depth. For example, it could well have been caught near the surface when the line or trawl was being shot or hauled, and indeed many reports have been received from line fishermen working off the coasts of Scotland and north-eastern England of seals stripping fish from hooks while lines were being hauled. The possibility of a seal taking a baited look on its way to the sea bottom is just as likely.

It has also been suggested that if seals lead a pelagic existence they may feed on quite different animals. As already indicated, all the evidence suggests a coastal habit, but even if it were to be demonstrated that seals do occasionally lead a pelagic life, it is unlikely that their food in the central North Sea, for example, would differ in any marked way from that in coastal waters.

It may be concluded, therefore, that the food of grey seals in the open North Sea would, in general, comprise the same types as those listed in Tables V and VI, and that any differences would be apparent more in the proportions of the various items than in the actual organisms.

In regions where the depths are too great to permit demersal feeding, as in the Faroe-Shetland Channel, and assuming that they linger long enough on passage to feed, grey seals would have to depend entirely on pelagic species. There is, however, no evidence that seals live or feed for any length of time over very deep waters. In such regions it might be expected that their diet would include higher proportions of squid and fish which are less used for human consumption.

Little is known about the movements of the common seal, but it is recognised as frequenting the more sheltered waters of estuaries, sea lochs, and passages between islands. There is no evidence to suggest that it departs from coastal waters at any time.

THE AVAILABILITY OF DIFFERENT SPECIES OF FISH IN COASTAL WATERS

The evidence on a whole suggests that seals prey on those species of fish which are most readily available. Since it has been shown that grey and common seals are mainly coastal in their distribution, it is pertinent to consider the stocks of fish frequenting these waters.

Tagging experiments on salmon have shown that some fish on returning to the British Isles from their feeding grounds, including the north-west Atlantic, follow a coastwise movement, sometimes from as far south as the west coast of Eire northwards along the Scottish west coast in making for the North Sea (Went, 1955). Other tagging experiments within the North Sea have also demonstrated a movement along the coast by salmon, presumably seeking their native river (Pyefinch and Woodward, 1955; Pyefinch and Shearer, 1957). Although various up-river "runs" of salmon are identified throughout the year, it is generally accepted that some salmon are present in Scottish coastal waters at all times of the year and that fish may be proceeding up-river at almost any time. For biological and physical reasons the numbers of salmon on the coast and the numbers attempting to run up-river, vary from month to month and from year to year.

Scottish coastal waters are rich feeding grounds for commercially important marine fish at all times of the year. Among marine fish cod, whiting, plaice and herring rank among the most numerous and the most valuable species exploited by Scottish fishermen. Not only do these waters serve as nursery grounds for cod, but from late autumn to spring of each year adult cod congregate to spawn in certain localities within or adjoining the coastal belt. Such localities include the Bell Rock area (outside the Firth of Forth), the Aberdeenshire coast, the Moray Firth, Scalloway Deep (Shetland) the north coast of Scotland, the Minch and the Firth of Clyde.

Whiting, particularly the younger individuals, occur in many coastal waters, including estuaries, at all times. Towards the end of the year coastal stocks are augmented by the movement inshore of whiting shoals.

The plaice, the commonest and most valuable flatfish in Scottish waters, is confined largely to the shallow water along the coast, and is particularly abundant in the sandy bays and estuaries which form the nursery grounds for the immature and adolescent fish until they are approaching their first maturity. On reaching this stage of their life cycle, they begin to move offshore, often including a northwards movement, to their spawning grounds, most of which are also located within or near the coastal zone.

Most of the fishing grounds for adult herring are located well outside Scottish coastal waters, but dense concentrations of young immature herring are found in most estuaries and sea lochs on both the east and west coasts throughout the winter. Sprats too congregate in these estuaries and lochs, and indeed both clupeoids may occasionally be found on the open coast about the same time.

Young saithe and lythe also frequent coastal waters, including estuaries and sea lochs, and adult fish approach the coast, notably in the Minch, during the winter and spring.

Although the haddock is the commonest gadoid species in Scottish fisheries it is predominantly an offshore fish and only enters coastal areas in some quantity to feed during the summer and autumn.

This short review of fish stocks stresses the importance of Scottish coastal waters as nursery grounds for the young of some of our commonest food fishes. It also indicates the seasonal presence in these waters of adult fish for spawning or feeding purposes. Adult fish of other deeper water species also penetrate the coastal belt in smaller and variable numbers from time to time and of course the shore zone is inhabited by its own typical rock, sand or mud-dwelling species, most of which have no direct commercial value.

Sampling of coastal fish stocks by trawl, seine, dredge and line fishing has been carried out by Scottish fishery research vessels since the beginning of the present century. These investigations show that cod, whiting, plaice, herring and sprats are the most numerous species in these waters and that their concentrations may sometimes have a pronounced local and or seasonal character. Research investigations over the years have also demonstrated that although certain small shore-dwelling species such as the goby and the viviparous blenny may occur in large concentrations their distribution is restricted to certain habitats. Furthermore, it is evident

that inside the three miles' limit the numbers of larger shore-dwelling species such as wrasse, lumpsucker, sea scorpion and rockling are small in comparison with the numbers of the commercially important species.

It is not surprising, therefore, that salmon, cod, whiting and saithe are prominent in the food of the grey seal, and salmon, whiting, saithe, clupeoids and pleuronectids in that of the common seal. Although seals eat a variety of less important fish, including conger eel, lythe and lumpsucker, and non-commercial species such as the rockling, sea scorpion, and blenny, the records of these fish in the seal stomachs are comparatively few, and indeed two of them, lythe and wrasse, often stated to be eaten by seals, do not appear in Tables V, VI and VII. (It is known, however, that lythe along with saithe and hake are eaten by seals in ground nets in the Minch). The reason for this would seem to be that the numbers of these less important fishes in the sea are small in comparison with the numbers of the more numerous commercially important types, and that they are clearly far too scarce to provide anything but a small part of the seal population's food requirements. Some fishes such as viviparous blennies and gobies, which are numerous locally, may sometimes be eaten fairly frequently by the common seal, but the overall food value of these small fishes is limited because of their small size and their restricted distribution. It would appear, therefore, that the evidence of the availability of the various food types fully supports the conclusion that the grey sea and common seals feed predominantly on those species which overall are most numerous and locally abundant and therefore most readily available, namely the commercially important salmonids, gadoids, pleuronectids and clupeoids. While the smaller common seal evidently concentrates more on smaller species of fish, the larger grey seal seems to prey more on the larger fish such as salmon, cod, saithe and lythe. This difference suggests that despite success in predation being dependent on numbers and availability of fish, the size and conspicuousness of the individual fish is also a factor of some importance. This could be regarded as indicating a preference by the grey seal for certain species, a feature which has already been noted in the reports by fishermen of salmon having been eaten by seals in bagnets, while lumpsuckers and flounders trapped in the same nets were left unmolested.

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SUMMARY

The food of seals in Scottish waters has been studied by the examination of the stomach contents of 368 grey seals and 175 common seals. These were obtained from a variety of sources and by different means throughout each year from 1958 to 1966 and covered the size-range of both species. A relatively high proportion of empty stomachs is explained to some extent by regurgitation of the stomach contents when seals find themselves trapped in nets. This, however, does not account for the very high proportion of empty stomachs in seals killed while hauled out on sand banks and beaches.

The food of both species of seal consists predominantly of fish, though crustaceans and molluscs are also eaten by young animals and by older seals in certain localities. On the Scottish east coast, from which most of the seals were obtained, the food of the grey seal consists chiefly of salmonids and gadoids with salmon, cod, whiting and saithe the principal individual species. Clupeoids, flatfishes and other species of commercial importance are also eaten.

The common seal, which is confined more to relatively sheltered waters, would appear to prey heavily on gadoids, particularly saithe and whiting, and to a less degree on salmon (though evidence from commercial sources suggests that predation on this fish may be high in estuaries and river mouths), flatfishes and clupeoids. This seal also preys on shore fishes of little or no commercial value wherever these occur in sufficient concentration.

The results of these studies have been considered in relation to the distribution of seals and to the occurrence of the various species of fish in Scottish coastal waters. This confirms that predation by seals is chiefly on those species of fish which are most readily available by reason of their numbers or their size. The fish eaten on the Scottish coast are those species which occur naturally in greatest concentration in coastal waters and therefore mainly comprise the commercially valuable salmonids, gadoids, pleuronectids and clupeoids.

In these days there are few fish of no commercial value, and these are mainly found close inshore where they are occasionally eaten locally, but in general the numbers or size of such species are too small to provide anything but a small proportion of the food of the seal population.

There is no evidence that grey or common seals lead a prolonged pelagic existence outside coastal waters, which for the present purpose may be regarded as extending to 10 or 12 miles offshore, but in any case their food in these waters is unlikely to differ to any marked extent from the normal, even though the species of fish and their proportions may vary from place to place.

REFERENCES

Berry, J. 1935. British mammals and birds as enemies of the Atlantic salmon (*Salmo salar*). *Rep. Avon biol. Res. 1934–35*, 31–64.

Booth, E. 1961. Scottish seaweed resources. *Elgard L. A. Natural Resources in Scotland. Symposium . . .* 1960, Edinburgh. Scott. Counc. (Dev. & Ind.) 1961, 181–186.

Boyd, J. M. 1962. Seasonal occurrence and movements of seals in north-west Britain. *Proc. zool. Soc. Lond.*, **138** (3), 385–404.

Boyd, J. M. and Laws, R. M. 1962. Observations on the grey seal (*Halichoerus grypus*) at North Rona in 1960. *Proc. zool. Soc. Lond.*, **139** (2), 249–260.

Boyd, J. M. 1963. The grey seal (*Halichoerus grypus* Fab.) in the Outer Hebrides in October 1961. *Proc. zool. Soc. Lond.*, **141** (4), 635–661.

Coulson, J. C. and Hickling, G. 1960a. The grey seals of the Farne Islands, 1958 to 1959. *Trans. nat. Hist. Soc. Northumb.*, n.s. **13** (6), 151–178.

—— 1960b. The grey seals of the Farne Islands. *Trans. nat. Hist. Soc. Northumb.*, n.s., **13** (7), 196–214.

—— 1962. The grey seals of the Farne Islands, 1st July 1960 to September 1961. *Trans. nat. Hist. Soc. Northumb.*, n.s. **14** (3), 90–100.

—— 1963. The grey seals of the Farne Islands, 1st October 1961 to 30th September 1962. *Trans. nat. Hist. Soc. Northumb.*, n.s. **14** (5), 170–183.

Craggs, J. D. and Ellison, N. F. 1960. Observations on the seals of the (Welsh) Dee estuary. *Proc. zool. Soc. Lond.*, **135**, 375–385.

Darling, F. F. 1947. Natural history in the Highlands and Islands. London, Collins, pp. xv, 303.

Fiscus, C. H. and Baines, G. A. 1966. Food and feeding behaviour of Steller and California sea lions. *J. Mammal.*, **47** (2), 195–200.

Harrison, R. J. 1960. Experiments with diving seals. *Nature, Lond.*, **188**, 1068–70.

Havinga, B. 1933. Der Seehund (*Phoca vitulina L.*) in der Holländischen Gewassern. *Tijdschr. ned. dierk. Vereen.*, ser. 3, D3. 79–111.

Hickling, G. 1957. The grey seals of the Farne Islands. *Trans. nat. Hist. Soc. Northumb.*, n.s., **12** (4), 93–133.

—— 1959. The grey seals of the Farne Islands. *Trans. nat. Hist. Soc. Northumb.*, n.s., **13** (2), 33–64.

Hickling, G., Rasmussen, B. and Smith, E. A. 1962. Innvandring fra Storbritannia til Norge av havert (*Halichoerus grypus*). Fiskets Gang, **48** (13), 199–205.

King, J. E. 1964. Seals of the world. London, *Brit. Mus. (nat. Hist)*, pp. 154.

Lockley, R. M. 1954. The seals and the curragh. London, J. N. Dent & Sons Ltd., pp. 149.

Millais, J. G. 1906. The mammals of Great Britain and Ireland, London.

Nehring, A. 1886. Über die Nahrung unserer Kabber-Arten. *Mitt. dt. Seefisch. Ver.* **2**, p. 101–5.

Øynes, P. 1964. Sel på norskekysten fra Finmark til Møre. *Fiskets Gang*, **50** (48), 694–707.

Pyefinch, K. A. and Shearer, W. M. 1957. The movements of salmon tagged in the sea, Altens, Kincardineshire, 1952, *Freshwat. salm. Fish. Res.*, No. 19, 7 pp.

Pyefinch, K. A. and Woodward, W. B. 1955. The movements of salmon tagged in the sea, Montrose, 1948, 1950, 1951. *Freshwat. Salm. Fish. Res.*, no. 8, 15 pp.

Rae, B. B. 1960. Seals and Scottish Fisheries. *Mar. Res.*, 1960 (2), pp. 39.

—— 1963. The food of grey seals. *Nature Conservancy. Grey seals and fisheries, Rep. Consult. Comm. on.*, Sect. 4, 28–33.

—— 1967. The food of cod in the North Sea and on West of Scotland grounds. *Mar. Res.*, 1967 (1), pp. 68.

RAE, B. B. and SHEARER, W. M. 1965. Seal damage to salmon fisheries. *Mar. Res.*, 1965 (2), pp. 39.
SERGEANT, D. E. 1951. The status of the common seal (*Phoca vitulina L.*) on the East Anglian coast. *J. mar. biol. Ass. U.K.*, **29**, 707–17.
SMITH, E. A. 1963. The population of grey seals. *Nature Conservancy. Grey seals and fisheries. Rep. Consult. Comm. on.*, Sect. 1, 15–18.
TELFER, I. M. and WATT, G. 1953. The grey seals of the Farne Islands, a preliminary report. *Trans. nat. Hist. Soc. Norhtumb.*, n.s., **10** (5), 165–182.
THIEL, P. H. van. 1966. The final hosts of the herring worm *Anisakis marina Trop. geogr. Med.*, **18**, p. 310–328.
WENT, A. E. J. 1955. Irish salmon and salmon fisheries, being the Buckland lectures for 1953. *London, Arnold*, pp. 93.

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